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Mapping of Total Lime Using Remote Sensing and GIS Technology, Case Study: Garmian District, Kurdistan Region-Iraq

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ABSTRACT

Calcium carbonate, lime, is a major component of the regolith, especially in arid and semi-arid regions. Lime affects soil characteristics, is a substantial store of earthly carbon, and is used in mineral investigation. Total lime is functioning component in the cultivation of Calcium carbonate and it is formed when calcium ions in hard water interact with carbonate ions to make limescale. Remote Sensing (RS) data and techniques integrated with Geographical Information System (GIS) play an important and prominent role in studying soil properties and how they are distributed by introducing the proportions and concentrations of chemical elements in the soil into GIS programs and then mapping the density of these elements and linking them spatially to the study area, and thus the spatial analysis of these elements. The study aims to map the distribution of the lime- rich regions utilizing remote sensing and geographical information system data and techniques integrated with field data observations in the Garmian region, Sulaimaniyah Province, Kurdistan Region, Iraq. Total of 80 well-distributed samples were tested precisely in the laboratory. Twelve samples were used as training samples in the classification, and the rest were used for checking the accuracy of the produced maps. The results also showed that Maximum likelihood classification is a reliable method that can be used on Landsat images to extract viable information on lime- rich regions and can predict the attendance and distribution of the lime-rich regions. It is clear that the amounts of calcium carbonate increase towards the study area south because the parent material is limestone and sandstone, which are rich in calcium carbonate, and also because of the low rates of rainfall in that area, which is not sufficient to dissolve the lime and wash it from the soil section.

Keywords: Geographical Information System, Remote Sensing, Kurdistan Region, Calcium Carbonate, Lime, Garmian.

1. Introduction

There are few studies of the distribution of carbonate by RS/GIS in the world, and there is a rare study of the same topic in Iraq or specifically in the Kurdistan Region, where the Lime is an important component because of its role in agriculture and construction of building component[1-3]. Calcareous soils are defined as soils that contain an amount of lime, CaCO3 that negatively affects the soil characteristics related to cultivating growth. Calcareous soils are widespread in the arid and semi-arid areas district of the world because of the lack of rainfall[4]. Soil lime is a major ingredient of the regolith, especially in arid and semi-arid regions such as Garmian[5]. Lime affects soil characteristics, is a substantial store of earthly carbon, and is used in mineral investigation[6]. Lime, as the main component of limestone, is the most utilized modification to balance soil pH where Lime can prevent sudden changes in the soil due to the presence of free carbons that can neutralize the acidity of the soil because of its high soil buffering capacity also to equipping calcium (Ca) for cultivates feeding[7,8]. Soil lime is also very important in agriculture, as it is considered one of the plant's nutrients because it contains calcium[9]. Limestone is a widespread sedimentary rock present in common geologic deposits. Lime has been utilized during extremely of kept story as structure substances, a cementing factor, and in cultivation to ameliorate acidulous soils[10]. The base rock installation of the various constructions in the Kurdistan Region of Iraq is carbonate rocks[1]. In the Kurdistan Region of Iraq, limestone is fundamentally utilized for cement manufacture[12]. As stated in[13], lime can be added to balance the impacts of acidulous rain in stream ecosystems. Lime is presently utilized to balance acidic conditions in both soil and water.

The important and useful data for active nutrient administration and, thus increased crop yields can be obtained by mapping patterns of spatial variation of soil properties[14]. Spatial variability of soil characteristics is affected by topographical features, land use type, soil depth, soil formation factors and

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processes, human activity and time[15-17]. RS and GIS are used in many areas related to the nature of the earth, the environment and the exploitation of lands in agricultural areas and urban growth[18,19], as well as the exploitation of the natural environment in the fields of tourism, which is a basic pillar of the country's economy[20]. This technique is also used in monitoring the occurrence of natural disasters such as forest fires, their area and how they are distributed to minimize the damage[21,22]. RS information and technologies have been utilized to monitor the earth, and obtain trustworthy data about what is below, above and on the Earth's surface[23]. RS data and techniques integrated with GIS play an important and prominent role in studying soil properties and how they are distributed by introducing the proportions and concentrations of chemical elements in the soil into GIS programs and then mapping the density of these elements and linking them spatially to the study area, and thus the spatial analysis of these elements[23]. Landsat 7 /Thematic Mapper (Landsat 7/TM) bands 3, 4, and 5 were used to produce thematic maps indicating lime, gypsum, and clay- rich surfaces using. TM is a precious support for soil mapping in arid areas[24,25] Specified the alternation in soil properties utilizing GIS techniques in the Iznik area in Turkey. A 2017 study also touched on how to identify and map some soil characteristics in Baquba town to benefit from them in the assessment and management of those soils[26].

Since lime is an important material in Agriculture and plant nutrition, which is also important in soil structure for building and constructions purposes in the Iraqi Kurdistan region, the problem here is the lack of a spatial map of the quantities and distribution of lime in the Garmian district, where it helps specialists to give an important idea of the quantities and distribution of lime in the region.

The study focuses on the following objectives:

1. The The use of RS and GIS Technology to study the lime in a large area such as the Garmian district.
2. Monitoring and spatial mapping of the distribution of lime in a short time by RS / GIS technology.
3. Make a map of the amounts of lime in the study areas.

2. Study Area

This study has focused on the Garmian region, which is located in the southern Kurdistan region, Iraq. The study area is adjacent to the city of Darbandikhan in the north and Kalar in the south, and from the western side, it is adjacent to the town of Kifri, but from the eastern side, it is close to the Iranian-Iraqi border. The study area is located between longitudes 44º 48′ 25″ E, 45º 14′ 16" E and latitudes 34º 35′ 01″ N, 35º 13′ 02″ N (Figure 1). The elevation of the study area ranges between 149.3 meters to 1063 meters above sea level. The study area is located within the foothills and Zagros Mountains, as mentioned by[27], and situated within the folds zone from the tectonic side[28]. The climate of the study area, as mentioned by[29], is continental semi-arid PE (Potential Evapotranspiration), there are others such as[30] described Iraq’s climate as a cool-humid in winter and hot-dry summer. The soil order of the Garmian region is mostly belongs to the Aridisols class[31]. On the other side, the soil moisture regime of the study area is Torric, as described by[32], and its soil temperature regime is classified as Hyperthermic[33]. It is worth noting that the field crops and natural plants found in the study area are one of the indicators during the survey of the study area, which is partly used for agriculture (e.g. *Triticum spp* and *Hordum spp*) while other barren lands remained, there are some types of native vegetation such as *Cynodon dactylon, Ammi majus*, *Triflolium resupinatum* and *Avena fatua*[34].

The rainfall of the area is seasonal, and occurred during Winter and Spring seasons, in general no rainfall during the Summer season[32]. There is a clear difference in the mean annual temperature in the study area between Winter and Summer (Garmian Agricultural Office/ and Derbendekhan Dame Office).

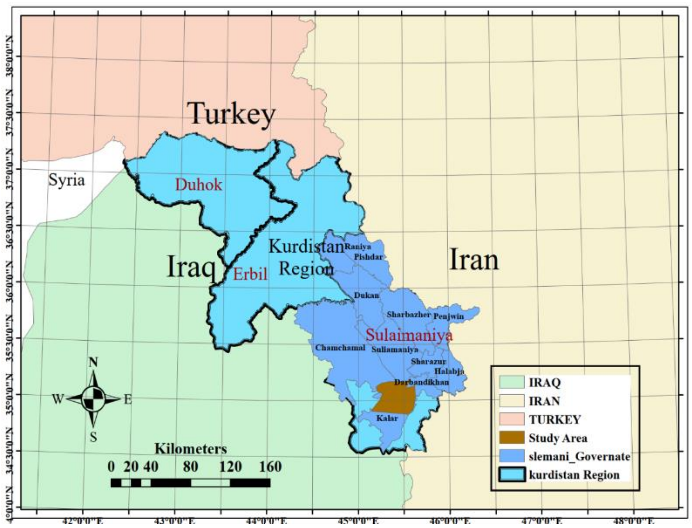

Figure 1: The study area located in the Garmian district, Sulaimaniyah Governate, KR, Iraq.

3. Methodology

This study tried to integrate field data and Enhanced Thematic Mapper/ Lansat (ETM/Landsat) satellite data to see how RS/GIS techniques may help to recognize the presence of calcium carbonate or lime-rich areas in the study area. Figure 2, shows the steps that have been followed to reach the supposed results.

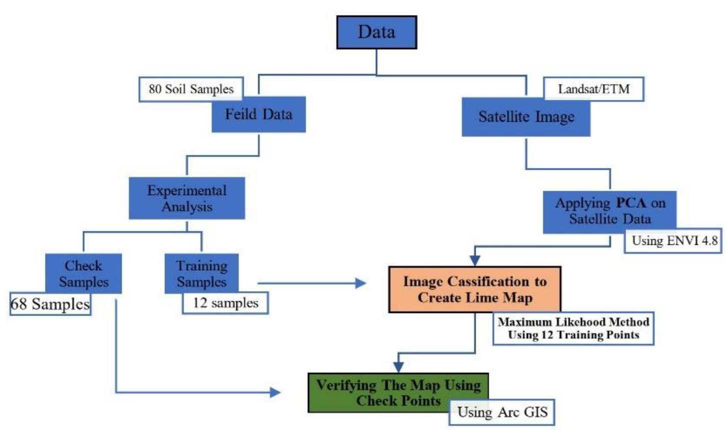

Figure 2: Methodological framework. Data collection, data processing, and expected results.

3.1 Data Used

Data resources have been used, including field data and freely access satellite data. The first dataset is a set of (8**0**) well-distributed soil samples within the study area. The samples were taken from the surface soil from a depth (0-30) cm. They, followingly, have been analyzed to estimate the existence of calcium carbonate. The second used dataset is Landsat 7 Enhanced Thematic Mapper Plus (ETM+) Level-1G which is provided by the United States Geological Survey (USGS); taken, in September; vegetation cover was rare in the study area. The ETM+ encompasses eight bands, including Visible Infrared (VNIR), Short Wavelength Infrared (SWIR), and Thermal Infrared (TIR) (Table 1)[35].

Table 1: The band, wavelength and resolution of Landsat 7/ETM+[35].

Bands	Wavelength micrometers (μm)	Resolution (meters)
Band 1 - Blue	0.45-0.52	30
Band 2 - Green	0.52-0.60	30
Band 3 - Red	0.63-0.69	30
Band 4 - Near Infrared (NIR)	0.77-0.90	30
Band 5 - Shortwave Infrared (SWIR) 1	1.55-1.75	30
Band 6 - Thermal	10.40-12.50	60 (30)
Band 7 - Shortwave Infrared (SWIR) 2	2.09-2.35	30
Band 8 – Panchromatic	0.52-0.90	15

3.2 Processing

Three main steps of processing have been conducted in this study. At beginning the processing of soil samples in the laboratory, and then RS analysis was done on satellite images using ENVI 4.8, and finally integration of them to display and map the distribution of lime-rich areas. As the provided Landsat 7/ETM+ Level 1 product had already been geometrically corrected, there was no need to apply more geometric correction. Therefore, using the FLASH tool in ENVI software and the Gain and Bias information of the image, which is given in the image metadata-file, the atmospheric correction was applied on six bands of the image, including (Blue, Green, Red, NIR, SWIR 1, and SWIR 2). This correction converts the Digital Number (DN) to radiance using gain and bias values according to the following equation (Eq. 1)[35].

$$L\lambda = gain * DN + bias \qquad \text{(Eq. 1)}$$

Where:

$L\lambda$ is the cell value as radiance; DN is the cell value digital number; gain is the gain value for a specific band; and bias is the bias value for a specific band.

3.2.1 Laboratory Analyses

The map prepared by[36] for reconnoitering soil survey, as well as a topographic map[37], were the base maps that were used, as the standard maps, for field data collection in the study area. Grid system method is used to select a total of 80 locations on the topographic map with six kilometers apart distance between each other. Contemporaneously, ground global coordinates of soil samples were taken using a GPS device. Table 2 shows a list of the 10 tested samples as an example. After being dried and grounded, a 2 mm sieve was used to sift the samples, and then hydrochloric acid was sued to estimate total carbonate, depending upon[38] and as described by[39].

Table 2: The soil samples, number, their coordinates and total lime contents.

No.	Latitude N	Longitude E	Total Lime
	(Decimal Degree)		g kg-1 soil
1	34.7089	44.9031	285
2	34.7424	44.9701	260
3	34.7291	45.0238	245
4	34.7312	45.0901	218
5	34.6944	45.1597	195
6	34.6541	45.1982	185
7	34.6469	45.3237	285
8	34.7034	45.3711	260
9	34.6645	45.4173	260
10	34.6664	45.5087	250

3.2.2 Satellite Analysis

Two widely-used classification methods were used to classify the satellite image, supervised Maximum Likelihood (ML) classification and Support Vector Machine (SVM) methods. like supervised classification needs training samples, a set of 12 samples were selected as training points covered the different ranges of lime level (Table 3) and (Figure 3).

No.	N (degree)	E (degree)	H (m) MSL	Total lime ($g\ kg^{-1}$)
1	34.8407	45.5376	149.3	155
2	34.9954	45.3664	421.3	155
3	35.1329	45.283	663.7	155
4	35.0026	45.3082	442.5	160
5	34.9783	45.1029	492.5	200
6	35.2152	45.1753	794.6	**200**
7	34.6113	45.2261	267.5	**200**
8	35.0133	44.9901	490	**205**
9	34.9716	45.69	592.1	**210**
10	35.0557	45.4589	803.4	355
11	35.0599	45.6599	394.8	400
12	34.9109	45.6305	332.9	405

These 12 points were, selected from the lowest level to the highest level. The 68 samples were used to estimate the accuracy of the classified maps in detecting of distribution of lime-rich areas. Figure (3) shows the distribution of training and checkpoints in the study area. Since the study area mostly contains very little vegetation during the capture of the image, the recorded reflection was mostly from the soil surface.

To minimize unnecessary data, the Principal Component Analysis (PCA) function was applied on all image bands, except the thermal and panchromatic before the classification [40]. This step was followed by applying ML and SVM classification methods. The training points' corresponding pixels were selected by the Region of Interest (ROI) tool in ENVI software and then used in supervised classification.

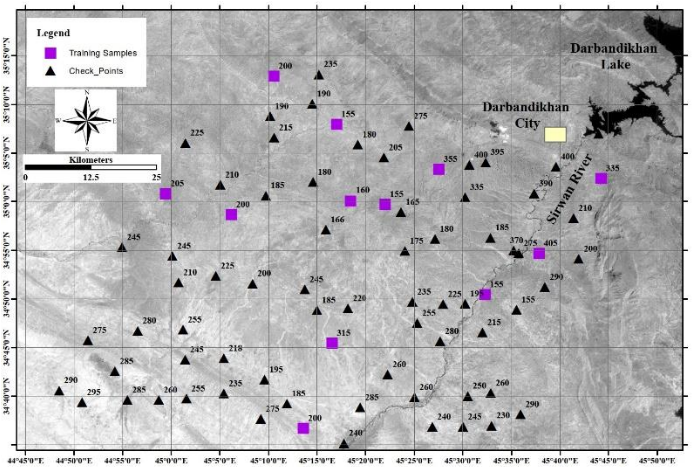

Figure 3: Distribution of Training and Checkpoints in the study area.

4. Results and Discussion

Two main sets of results were produced. Firstly, the results produced from laboratory analyses, and secondly, from the maps.

4.1 Total Lime

As displayed in Table (2), the total lime ranges from 155 g kg -1 soil to 405 g kg -1. Commonly, this area is a lime-rich area because it has calcareous soils, which are one of the major parent materials. These outputs simply reflect the influence of calcification and decalcification processes which result in the emergence of the illuvial subsurface (calcic) horizon, which is observable in the study area[5].

4.2 Mapping

Two thematic maps were created, as per the applied methods (Figures 4 and 6). The 12 training points were used to classify the image, while the rest were used as checkpoints. The checkpoints are displayed in different shapes on the maps. Figure (4) shows the result of applying ML classification on the PCA image. The PCA image itself was created from ETM bands including b1, b2, b3, b4, b5, and b6_1. In the second place, (Figure 5) shows the application of the Support Vector Machine (SVM) classification. Both maps are supposed to display a possible distribution of lime-rich areas in the form of some chromatic site.

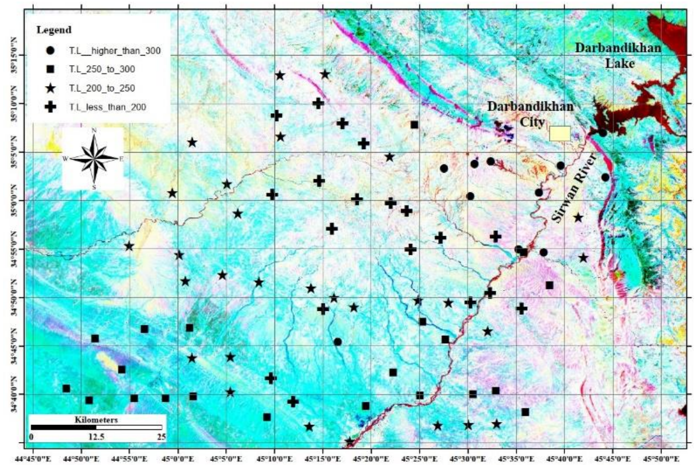

Figure 4: Map of TL distribution created by ML classification method (ML_ Map).

The results showed that ML classification was better in terms of recognizing different soil components and patterns. For example, ML could completely distinguish the water body of Darbandikhan Lake (see Figure 4, upper right). At the same time, in SVM classification, there is a rare contrast between the water body and its neighborhood (see Figure 6, upper right). The ML even could recognize the whole way of Sirwan River in the same chronic characteristic as the lake.

Figure (5) shows a chromatic legend for describing the ML map (Figure 4), within, we can see the categories of lime-rich areas. Three classes were defined and used to classify the image using the ML method. The low class stands for Total Lime (TL) <200, Average class stands for 200< TL< 250, and the high class stands for TL >250 g per kg of soil sample. The amounts of lime were classified into three low, medium and high varieties, as the amount of lime ranges from 150 g / kg soil and 400 g / kg soil, these are the ratios found in the areas of the Garmian district [41], three varieties were selected to show the areas with low, medium and high amounts of calcium carbonate according to the quantities found in the study area.

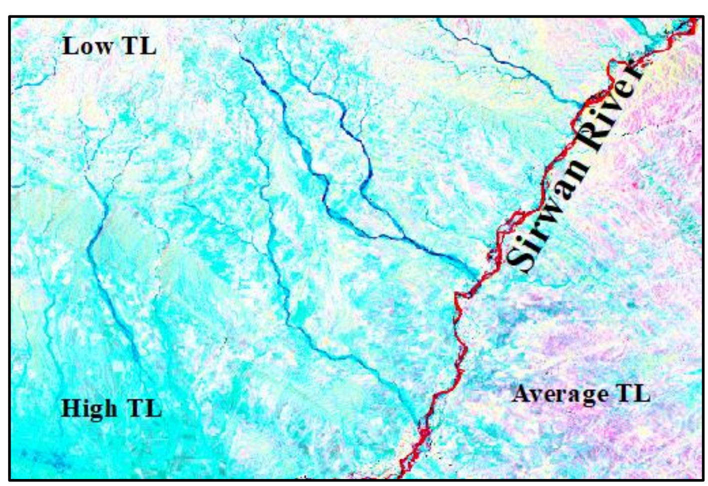

Figure 5: Chromatic legend that shows the relation between the colors and the classes.

According to this chromatic legend (Figure 5), the thematic map created by the ML method (Figure 4) shows the TL- rich area as cyan color. The areas of denser cyan color show the presence of a high probability of TL presence in that area (see Figure 5, lower left). In the area where purple and cyan area, or cyan and white area are mixed, the TL is average. Finally, in the white area, or the area where purple and white areas are mixed, the TL is regarded as the Low TL class. It is clear from (Figure 5) that the amounts of calcium carbonate increase towards the south of the study region because the parent material is limestone and sandstone, which are rich in calcium carbonate, and also because of the low rates of rainfall in that area, which is not sufficient to dissolve the lime and wash it from the soil section.

Regarding the TL classes and the distribution of checkpoints in ML-Map (Figure 4), it easily can be observed that the checkpoints which is less than 200 g/kg (the black cross +) are mostly located in the area which is recognized as Low TL (mostly white areas) on the ML-Map. It shows that the ML classification could help to find a low TL area. In the same way as the low TL area, the checkpoints whose value is average 200g/kg < TL< 250 g/kg (the black stars ★) are mostly located in the areas recognized as Average TL on the ML-Map. Furthermore, the checkpoints whose TL value is higher than 250 (the black square ■ and circles ●), which are regarded as High class, are mostly located in the regions which have been predicted and assigned as High TL (Cyan area). Although the overlap of checkpoint classes and classified ML-Map is not complete, is still satisfying, especially in comparison with SVM-Map.

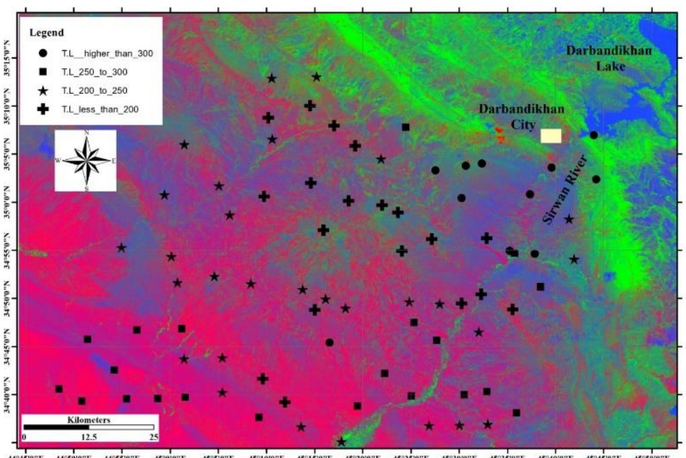

Figure 6: Map of TL distribution created by SVM classification method (SVM_Map).

Conclusion and Recommendations

The study showed that RS and GIS data and techniques could be useful in monitoring and mapping lime distribution, especially for vast areas in which field observations could be tough and too much time required. It's highly suggested to get advantages of different satellite sensors with another spectral and resolution (e.g. Hyperion and Spot) to reach additional reliable and precise distribution maps. Based on the results, integration of remote sensing and field observations can be used effectively to get reliable information on where and to what level the study area may be rich with lime. It should be considered that the quality and precision of the outputs highly depend on the field observations' quality, as well as the spatial and spectral resolution of the satellite image. It was also shown in this study that (ML) is more efficient than (SVM) for classification and total lime.

Conflict of interests

None

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